Course curriculum of Robotics & Artificial Intelligence.

Compulsory Courses.

1. Artificial Intelligence (Includes LAB sessions)
2. Fundamentals of Robotics
3. Machine Learning
4. Robot Sensing and Vision

Compulsory Labs

1. Programming Laboratory
2. Robot Design Laboratory

Electives (enrolled by students)

CS 514 – Mathematics for Computer Science

CS 563 – Neural Networks for Natural Language Processing

CS 590 – Deep Learning

CS 560 – Virtual and Augmented Reality Systems

CS 577 – C Based VLSI Design

CS 666 – Mobile Robotics

EE 624 – Speech Technology

EE 722 – Video Analytics

ME 609 – Optimization Methods in Engineering

DA526 - Image Processing with Machine Learning

DA 624 – NLP with Large Language Models

Electives offered (any five to be chosen):

CS514 - Mathematics for Computer Science

CS571 - Human Computer Interaction

CS530 - Machine Learning using Cloud Computing

CS551 - Wireless Networks

CS563 - Neural Networks for NLP

CS565 - Intelligent Systems and Interfaces

CS566 - Speech Processing

CS560 - Virtual and Augmented Reality Systems

CS570 - Fundamentals of Information Retrieval

CS577 - C Based VLSI Design

CS578 - Internet of Things

CS590 - Deep Learning

CS666 - Mobile Robotics

DA526 - Image Processing with Machine Learning

DA671 - Introduction to Reinforcement Learning

DA624 - NLP with Large Language Models

EE523 - Introduction to Machine Learning

EE535 - Advanced Topics in Machine Learning

EE550 - Linear Systems Theory

EE551 - Estimation and Identification

EE659 - Fuzzy Logic and Neural Networks

EE626 - Pattern Recognition and Machine Learning

EE657 - Intelligent Sensors and Actuator

EE660 - Modeling and Control of Power Electronic Converters

EE646 - Optical Measurement Techniques Applications

EE656 - Robust Control

EE553 - Optimal Control

EE554 - Nonlinear Systems and Control

EE694 - Introduction to Parallel Computing

EE653 - Modeling and Simulation of Dynamic Systems

EE722 - Video Analytics

ME629 - Design of Mechatronic Products

ME674 - Soft Computing in Engineering

ME608 - CAD CAM

ME615 - Rotor Dynamics

ME543 - Computational Fluid Dynamics

ME645 - Mechatronics

ME609 - Optimization Methods in Engineering

ME644 - Modern Control

DD559 - Design for Additive Manufacturing

DD533 - Auditory and Voice Interaction Design

DD509 - Interaction Design

DD516 - Digital Human Modelling and Simulation in Product Design

DD518 - Representation Techniques for Animation

Course structure of courses undertaken by students

CS 514 – Mathematics for Computer Science

Review of sets, functions, relations; Logic: formulae, interpretations, methods of proof in propositional and predicate logic; Number theory: division algorithm, Euclid's algorithm, fundamental theorem of arithmetic, Chinese remainder theorem; Combinatorics: permutations, combinations, partitions, recurrences, generating functions; Graph Theory: isomorphism, complete graphs, bipartite graphs, matchings, colourability, planarity; Probability: conditional probability, random variables, probability distributions, tail inequalities.

CS 563 – Neural Networks for Natural Language Processing

Introduction: Different levels of NLP; Text Normalization: sub-word tokenization; Recap of Neural Network Fundamentals: Feed Forward network, Computational Graph, Backpropagation, Convolutional Neural Network, Recurrent Neural Networks and variants; Neural models for NLP Tasks: Vector Semantics, Neural Language Models, Sequence Labeling Tasks, Sequence to sequence learning tasks, Encode-Decoder Models, Attention models and Transformers, Contextualized word embedding; Large-scale Neural Models: Transformer and variants based large language models; Multi-lingual Learning: Cross-Lingual Embedding, Transfer Learning; Applications: Machine Translation, Conversational Agents etc.

CS 590 – Deep Learning

Machine Learning: Fundamentals; Neural Network: Perceptrons, Back Propagation, Over-fitting, Regularization. Deep Networks: Definition, Motivation, Applications; Principal Component Analysis; Restricted Boltzmann Machine; Sparse Auto-encoder; Deep Belief Net; Hidden Markov Model. Convolution Neural Network (CNN): Basic architecture, Activation functions, Pooling, Handling vanishing gradient problem, Dropout, Greedy Layer-wise Pre-training, Weight initialization methods, Batch Normalization; Different CNN Models: Alex Net, VGG Net, Google Net, Res Net, Dense Net, MIL, Highway Network, Fractal Network, Siamese Net; Graphical Model: Bayes Net, Variational Auto-encoders. Sequence Learning: 1D CNN, Recurrent Neural Network (RNN), Gated RNN, Long short-term memory (LSTM). Generative Modeling: Generative adversarial network. Zero Shot Learning. Applications.

CS 666 – Mobile Robotics

Introduction to Mobile robot architectures, Control Paradigms, Sensors and actuators. Learning Approaches for robots. Navigation Strategies, Detecting and handling Novelty. Behavior-based robotics, AlE and their application to robots. Case studies of learning robots, Laboratory sessions will include study and implementations of the above methodologies using real robots. Reinforcement Learning, Genetic Algorithms, Swarm based Algorithms.

DA 624 – NLP with Large Language Models

History of evolving NLP problems, natural language processing: Words, Syntactic Parsing, Dependency Parsing; n-gram Language Model; natural language understanding, language generation, Neural models basics: Recurrent Neural Network, Attention and Transformer; Neural Language Models, Different formulations: Encoder only, Encoder-decoder, Decoder only; training and fine-tuning Large Language Models: BERT, RoBERTa, ChatGPT, LLama, Prompt Engineering; Case studies and future challenges.

Recent papers from top tier ML/NLP conferences and organizations like Microsoft Research, Google Research, Amazon and Walmart Labs, etc.

CS 577 – C Based VLSI Design

Electronic Design Automation flow: Overview of high-level synthesis, logic synthesis and physical synthesis. High-level Synthesis (HLS) Fundamentals: Overview HLS flow, Scheduling Techniques, Resource sharing and Binding Techniques, Data-path and Controller Generation Techniques. Impact of C-coding style on Hardware: Data types, Synthesis of Loops, Functions, RAM, ROM, Shift register inference from arrays. Impact of Compiler Optimization in HLS results: Impact of Compiler optimizations like copy propagation, constant propagation, common sub-expression elimination, loop transformations, code motions, etc., in HLS results. Advanced Topics: Relative Scheduling, IO scheduling modes - cycle fixed scheduling modes, super-fixed scheduling modes, free-floating scheduling mode, Pipelining, Handshaking, System Design, High-Level Synthesis for FPGA. RTL Optimizations Techniques: Various optimization techniques to improve latency, area and power in C-based VLSI designs. High-level Synthesis Verification: Simulation based verification, Translation validation. Equivalence Checking between C and RTL.

ME 609 - Optimization Methods in Engineering

Introduction to optimization; Formulation of optimization problems; Classical optimization techniques. Linear Programming. Non-linear Programming; single variable, multi-variable

and constrained optimization. Specialized algorithms for integer programming and geometric programming; Non-traditional optimization algorithms

EE 722 – Video Analytics

Introduction to Video Analytics; Ontologies in Computer Vision; Recognition Problems in Computer Vision; Surveillance Video Analytics – System Architecture, Ontologies, Research Issues and Information Visualization; Background Modeling for Static and Pan-Tilt Cameras; Object Detection - Features, Bag of Words Formulation, Dictionary based Approaches, CNN based Methods; Human detection and localization; Object Tracking - Particle Filter, Kernel based Tracker, L1 Tracker, Discriminative Model based techniques, Multiple Object Tracking, Activity Recognition – Human Action Recognition, Scene Activity Identification; Surveillance Analytics; Television News Broadcast Video Analytics - System Architecture, Ontologies, Research Issues and Query Response Visualization; Text Detection and Recognition; Face Detection, Tracking, Linking and Recognition; Broadcast Segmentation - shot, scene and story segmentation; Features and Algorithms for Video Event Discovery; Broadcast Analytics; Research Directions in Video Analytics.

CS-560 Virtual and Augmented Reality Systems

Introduction: VR/AR experience; role of human sensory organs; hardware; software; interaction; Overview of interactive software development life cycle; Computer graphics: 3D pipeline; overview of pipeline stages; Computer vision: basic representation techniques; overview of object detection and recognition; introduction to SLAM; Immersive content delivery: Representation and projection techniques for 360 video, stereoscopic multimedia content; Basic HTTP-based adaptive streaming architectures (DASH,HLS); adaptive FoV-based streaming; 360 video delivery over CDNs; Edge-Cloud support for VR/AR applications; Future AR/VR applications (holoteleportation, telepresence, etc.); System design and implementation: Unity; VR and AR SDKs; case studies on VR and AR systems.

EE 624 – Speech Technology

Applications, pattern recognition, feature extraction, modeling, testing; Speech recognition: Objective, issues, block diagram description, classification, development of speech recognition system using vector quantization (VQ), dynamic time warping (DTW), Hidden Markov Model (HMM) and Neural networks (NN); Speech synthesis: Objective, issues, block diagram description, classification, development of speech synthesis system using

articulatory, parametric, concatenative and HMM based approaches; Speaker recognition: Objective, issues, block diagram description, classification, development of speaker recognition system using VQ, DTW, GMM, NN and HMM; Speech enhancement: Objective, issues, block diagram description, classification, enhancement of noisy speech, reverberant speech enhancement and multi-speaker speech processing.

DA526 - Image Processing with Machine Learning

Fundamentals of machine learning: dataset generation, augmentation, standardization, train/validation/test set preparation, cross-validation, model training and evaluation; Supervised and unsupervised learning, regression and classification, artificial neural networks, deep architectures. Image processing with Machine Learning: Introduction to image processing; Machine learning workflow for image processing; Introduction to software tools for image processing and machine learning; Elements of visual perception, imaging geometry; Image acquisition: depth of field, auto exposure, high dynamic range imaging; Image processing in spatial and frequency domains, super-resolution; Image restoration: deblurring, dehazing, inpainting; Image segmentation: semantic segmentation; Color image processing, pseudo coloring; Image representation and image descriptors; Image recognition: localization and classification; Machine learning in video processing.

RA 502 – Artificial Intelligence

1.Searching Techniques: uninformed search strategies, informed (heuristic) search strategies, local search algorithms, searching in non-deterministic and partially observable environment, adversarial search.

2.Temporal Probability models and inference in temporal models: filtering, prediction, smoothing, most likely explanation, Dynamic Bayesian Networks, Hidden Markov Model, Kalman Filter, Extended Kalman Filter, Particle Filter, Learning Probabilistic Models.

3.Decision making: Markov Decision Processes (MDPs), Partially Observable MDPs (POMDPs).

4.Learning: Introduction to supervised learning, unsupervised learning, and reinforcement learning.

LAB – NumPy, Matplotlib, Pandas, Scikit learn, Seaborn, GA, Supervised and Unsupervised Learning.

RA 501 – Fundamentals of Robotics

Introduction to Robotics: Types and Classification of robots; Science and Technology of Robots. Rigid Body Transformation: Overview of Rigid Body Kinematics; Homogeneous Transformation; Link Transformation Matrices. Forward and Inverse Kinematics & Dynamics of Robots. Planning and Control of Robots.

RA 505 – Robot Sensing and Vision

Geometrical Computer Vision: Pinhole camera model, camera calibration, stereo vision. Sensor: Binary, monochrome and RGB imaging sensors; ultrasound rangefinders; optical rangefinders - LASER scanner, static LED array; structured lighting, dynamic focusing; interfacing of vision sensors; velocity sensors, accelerometers, tactile sensors.

Image Processing: Basic operations, transformations, image features, Motion estimation, Object Detection and Recognition, Object Tracking.

RA 506 – Machine learning

1.Introduction to supervised and unsupervised learning frameworks;

2.Dimensionality reduction: Feature selection; PCA;

3.Supervised learning: Bayesian classification, Perceptrons, Multi-layer perceptron, RBF Networks, Decision Trees, Support Vector Machines, Convolutional Neural Networks, Recurrent Neural Networks;

4.Unsupervised learning: K-Means clustering, DBSCAN, Non-parametric Estimation, Mean-shift clustering; Classification performance analysis; Ensemble methods – Boosting and Bagging